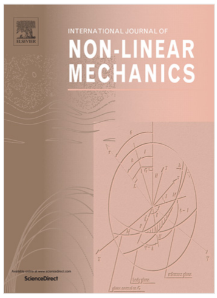
Accepted Manuscript



Nonlinear analysis of ionic polymer-metal composite beams using the von Kármán strains

Jayavel Arumugam, J.N. Reddy

PII: S0020-7462(17)30666-2
DOI: https://doi.org/10.1016/j.ijnonlinmec.2017.10.007
Reference: NLM 2911

To appear in: *International Journal of Non-Linear Mechanics*

Received date : 28 September 2017
Accepted date : 9 October 2017

Nonlinear Analysis of Ionic Polymer-Metal Composite Beams Using the von Kármán Strains

Jayavel Arumugam and J. N. Reddy
Department of Mechanical Engineering
Texas A&M University, College Station, TX 77843-3123, USA
e-mail: jnreddy@tamu.edu

Abstract

In this study, nonlinear analysis of ionic polymer-metal composite (IPMC) strips using the Euler–Bernoulli beam theory with the von Kármán nonlinear strain is presented. The governing equations are derived using a variational formulation based on a thermodynamic framework. The nonlinear extensions to the linear theory are made in such a way that the resulting form of the coupling between deformation and solvent concentration remains simple. A hybrid finite element-finite volume numerical solution and a operator-split time stepping scheme are formulated for obtaining numerical solutions of the transient electromechanical response. The model is phenomenological, but it is capable of simulating the transient response of IPMC strips under general loading conditions, and it would be useful in the design of mechanisms with IPMC strips as components. The results of the nonlinear analysis are compared with the corresponding linear results for a cantilever beam like IPMC strip. Significant differences in simulation results of tip deflection, solvent concentration, and beam configurations are observed between the linear and the nonlinear beam theory. The differences are due to coupling between the bending and the axial stiffness as properly formulated in the proposed nonlinear theory.

Key words: Beams; Electromechanical response; Ionic polymer-metal composite; Nonlinear analysis

1 Introduction

1.1 Background

Ionic polymer-metal composites [1, 2] are a class of electro-active smart materials that deform upon the application of an electric potential. A schematic of an IPMC strip is shown in Figure 1. IPMC strips are composed of an anionic polymer matrix like Nafion (perfluorosulfonate) or Flemion (perfluorocarboxylate) [3] infused with a suitable solution (with cations like Li^+ or tetrabutylaluminium TBA^+). The surface is coated with a conductive